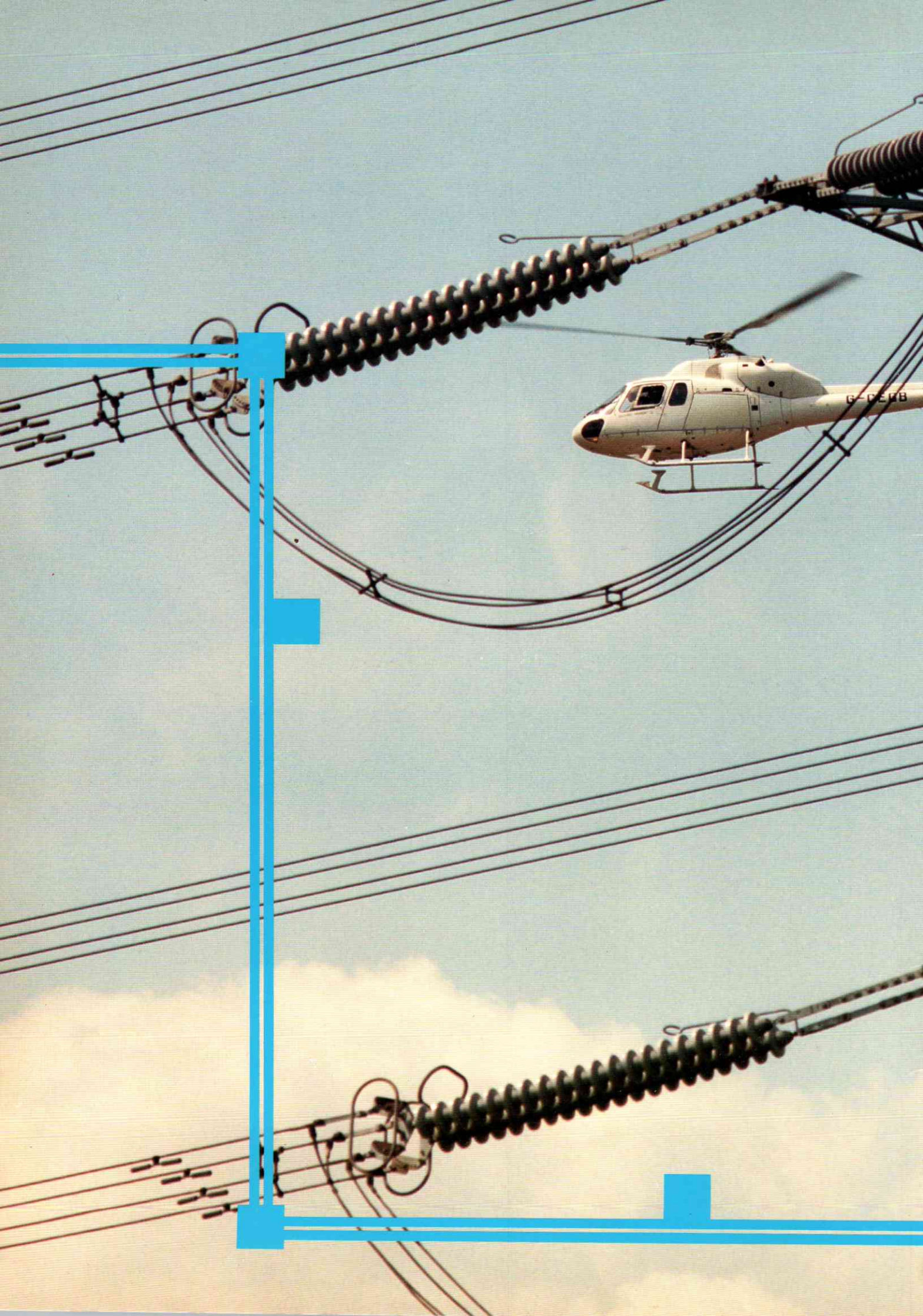
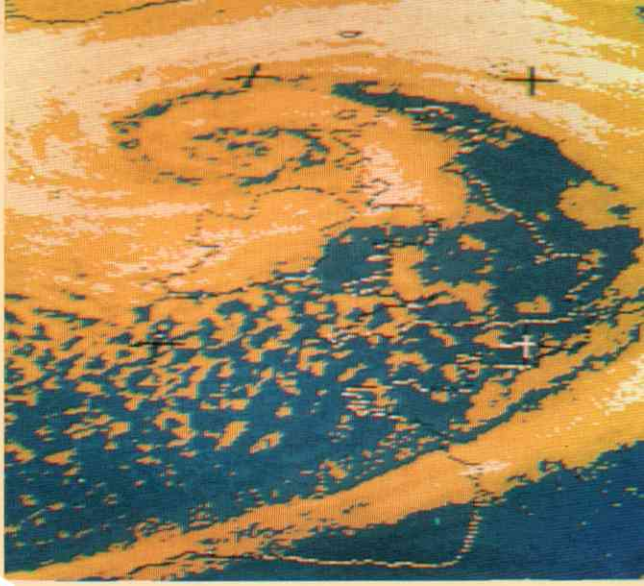
National
Control
Centre



The Transmission System



Satellite picture of weather system.

SCOTLAND

SCOTLAND

HARKER

HAWTHORN PIT

NORTON

HUTTON

HEYSHAM

STANAH

PADIHAM

DRAX

CREYKE BECK

THORPE MARSH

GRIMSBY WEST

WYLFA

STALYBRIDGE

COTTAM

DINORWIG

FFESTINIOG

CELLARHEAD

TRAWSFYNYDD

RUGELEY

RATCLIFFE

IRONBRIDGE

WALPOLE

NORWICH MAIN

ENDERBY

FECKENHAM

BRAMFORD

WYMONDLEY MAIN

EAST CLAYDON

AMERSHAM MAIN

PEMBROKE

DIDCOT

CULHAM

GRAIN

MELKSHAM

CANTERBURY NORTH

HINKLEY POINT

BRAMLEY

FLEET

SELLINDGE

NURSLING

TAUNTON

NINFIELD

DUNGENESS

FRANCE

ALVERDISCOTT

BOLNEY

AXMINSTER

LOVEDEAN

FAWLEY

EXETER

INDIAN QUEENS

Lines or cables

Operating voltage

400 kV AC

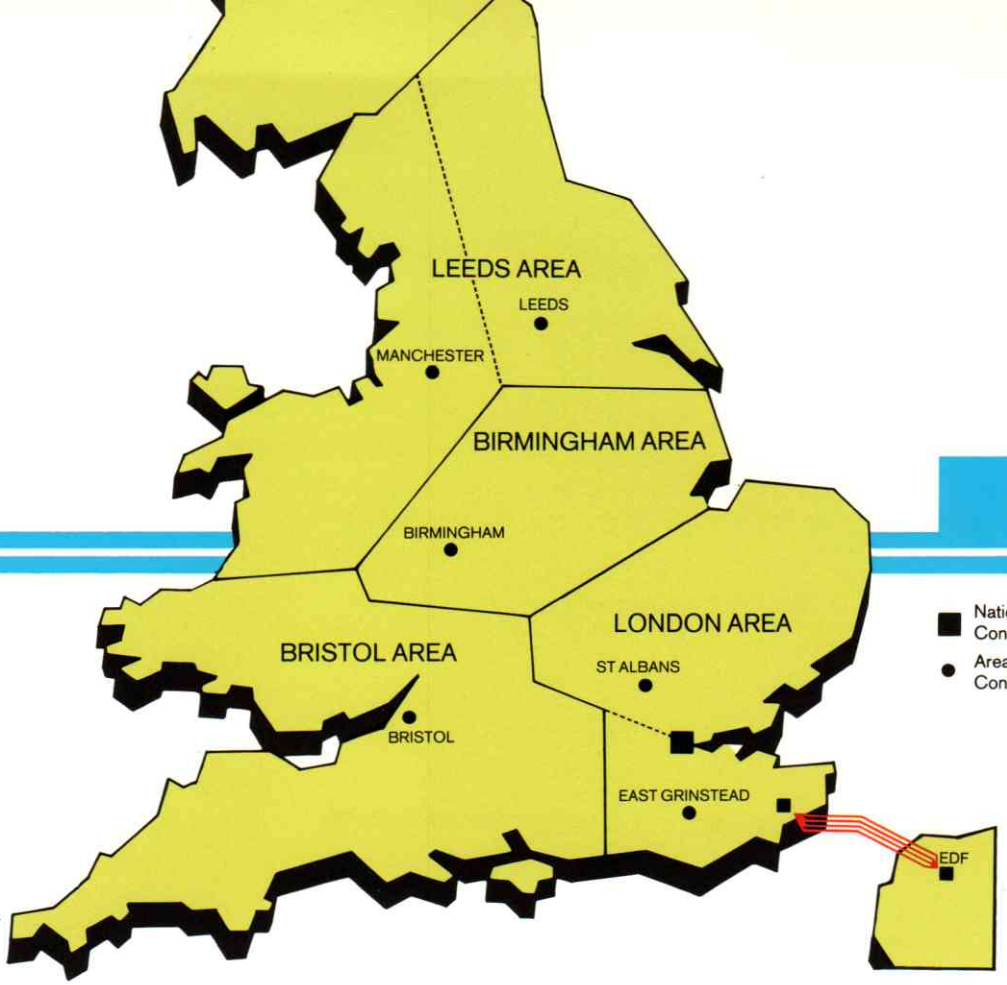
275 kV AC

Introduction

Electricity is generated at power stations and transmitted in bulk via the 400/275kV transmission system to the principal distribution networks for distribution to individual industrial, commercial and private customers.

The National Control Centre directs the economic generation of electricity and the secure operation of the transmission system in England and Wales.

Weather forecast data being received from the Meteorological Office.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LEEDS
MANCHESTER
BIRMINGHAM AREA
BIRMINGHAM
LONDON AREA
ST ALBANS
BRISTOL AREA
BRISTOL
EAST GRINSTEAD
EDF
National Control Centre
Area Control Centres

The Power System

The transmission system operates at 400,000 volts (400kV) and 275,000 volts (275kV) and all large modern power stations are directly connected to it.

The main power system consists of over 70 power stations (containing approximately 350 generators) having a combined output capacity of 55 gigawatts (GW) which is subject to Central Despatch to meet the maximum customer demand of 48GW. There are approximately 5400 route kilometres of 400kV transmission lines and cables, and 1900 route kilometres of 275kV circuits.

When the original 132kV transmission network, known as the Grid System, was first built it was designed to operate as many independent sections, each one with sufficient generating capacity to cover its own local demand. Subsequently, these individual areas were connected together to provide additional security in an emergency. As the demand for electricity grew the need for the bulk transfer of power across the country arose and so the 275kV Supergrid system was constructed and superimposed on the original 132kV Grid System. Some years later this 275kV system was updated and strengthened to form an integrated 400/275kV main transmission system, capable of handling large scale movements of electrical energy.

Large high efficiency power stations were built to take advantage of the economics of scale and were sited close to fuel sources to minimise transport costs. This resiting of generation close to fuel sources rather than demand centres made necessary the bulk transmission of energy over the Supergrid system.

The Supergrid system has been planned to have great flexibility of response to the ever-varying customer demand for electricity and to the changing patterns of generation caused by variations in the price of this generation. Using the strength and completeness of this interconnection it is possible to operate the power stations in such a way that maximum economy of generation is achieved.

Furthermore, a high degree of security of supply is provided, so that a sudden loss of generation at one power station can immediately be made good by an equivalent increase in output from a number of other power stations in other parts of the country. In like manner, when faults occur on the Supergrid system, power transfers are normally redistributed without disruption to the customer.

Wide daily and seasonal variations in the customer's demand for electricity occur in this country. Typically, the demand for electricity during the daytime is twice the demand during the night and the maximum demand in winter is four times the minimum demand in summer. Since the total amount of generating plant installed is designed to meet the highest customer demands in winter, large savings in cost are possible during the remainder of the year by arranging that just sufficient plant is run at all times to meet the customer's demand and ensuring that the most economical plant is utilised. Extensive planning is carried out to ensure that, throughout the year, optimum use is made of the generating plant and transmission equipment.

Controlling the System

The National Control Centre in London directs the economic generation of electricity and the secure operation of the transmission system in England and Wales through six Area Control Centres.

These six Area Control Centres are located in Manchester, Leeds, Birmingham, St Albans, East Grinstead and Bristol and each is in direct communication with all the power stations and grid switching stations within its geographical area.

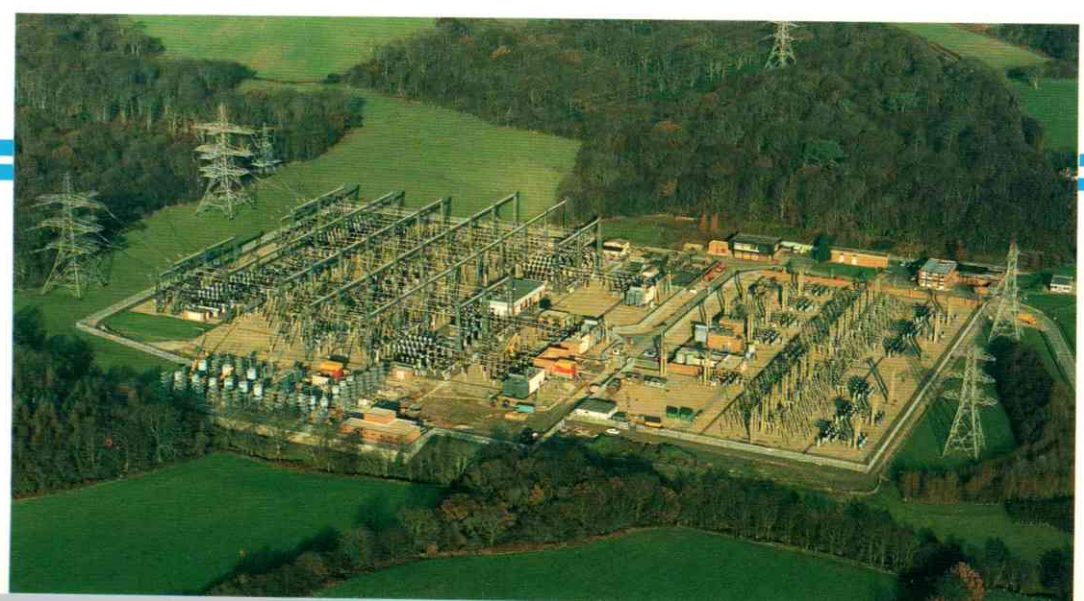
National Control is responsible for ensuring that the whole English and Welsh power system operates economically and securely as an integrated whole. Operating programmes for Area Control Centres are arranged in advance and are monitored and optimised continuously, so that the most economical plant available is used to supply the national demand for electricity. In operating the system, National Control must ensure that in the event of a fault, circuit loadings are never allowed to reach levels at which the transmission system would be overloaded.

National Control is also responsible for commercial trading with Scotland and France and is in direct communication with their Control Centres. Trading with these external utilities is a regular feature of national operation.

National Economic Operation

The customer demand for electricity is influenced by a variety of factors, the principal ones include the overall economic prosperity of the nation, seasonal variations, day of week, time of day and weather. The time-related influences have a significant effect on the shape and level of the demand profile as illustrated. Weather, through its various components of temperature, wind speed, cloud cover and precipitation affect electricity demand through a variety of customer applications. Those applications particularly influenced by weather include space and water heating, refrigeration and food freezing, air conditioning and artificial lighting. The customer response to these weather influences is complex, requiring sophisticated mathematical analysis to interpret.

To meet these demand variations economically, it is necessary to predict continuously, and as accurately as possible, the customer electricity demand for the next 24 hours. This is achieved by statistically analysing past records of demand and weather observations stored on a computer-held databank, in order to formulate mathematical models of electricity demand. The mathematical models are then used with specialised weather forecasts to form forecasts of electricity demand. These in turn are then translated into a generation programme which ensures that exactly the right amount of generating plant is economically selected, with a small reserve to cover inaccuracies in the demand forecast that may occur and any failure of generating plant during the day.

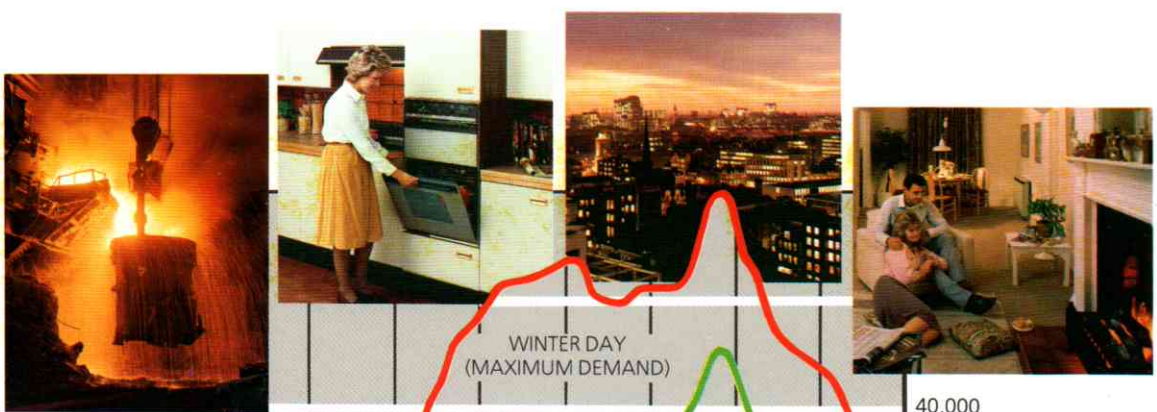


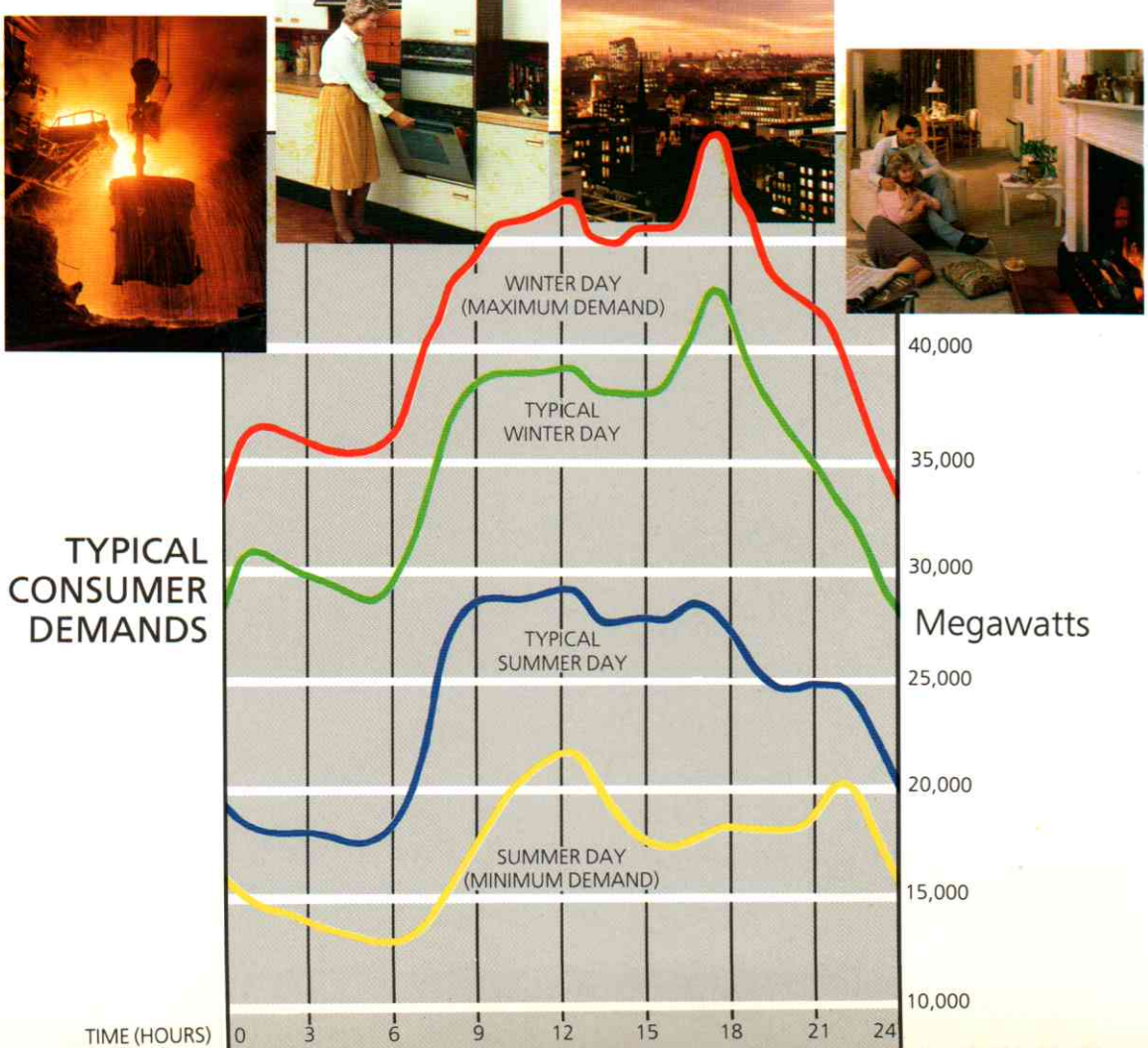
Ninfield substation in Sussex.

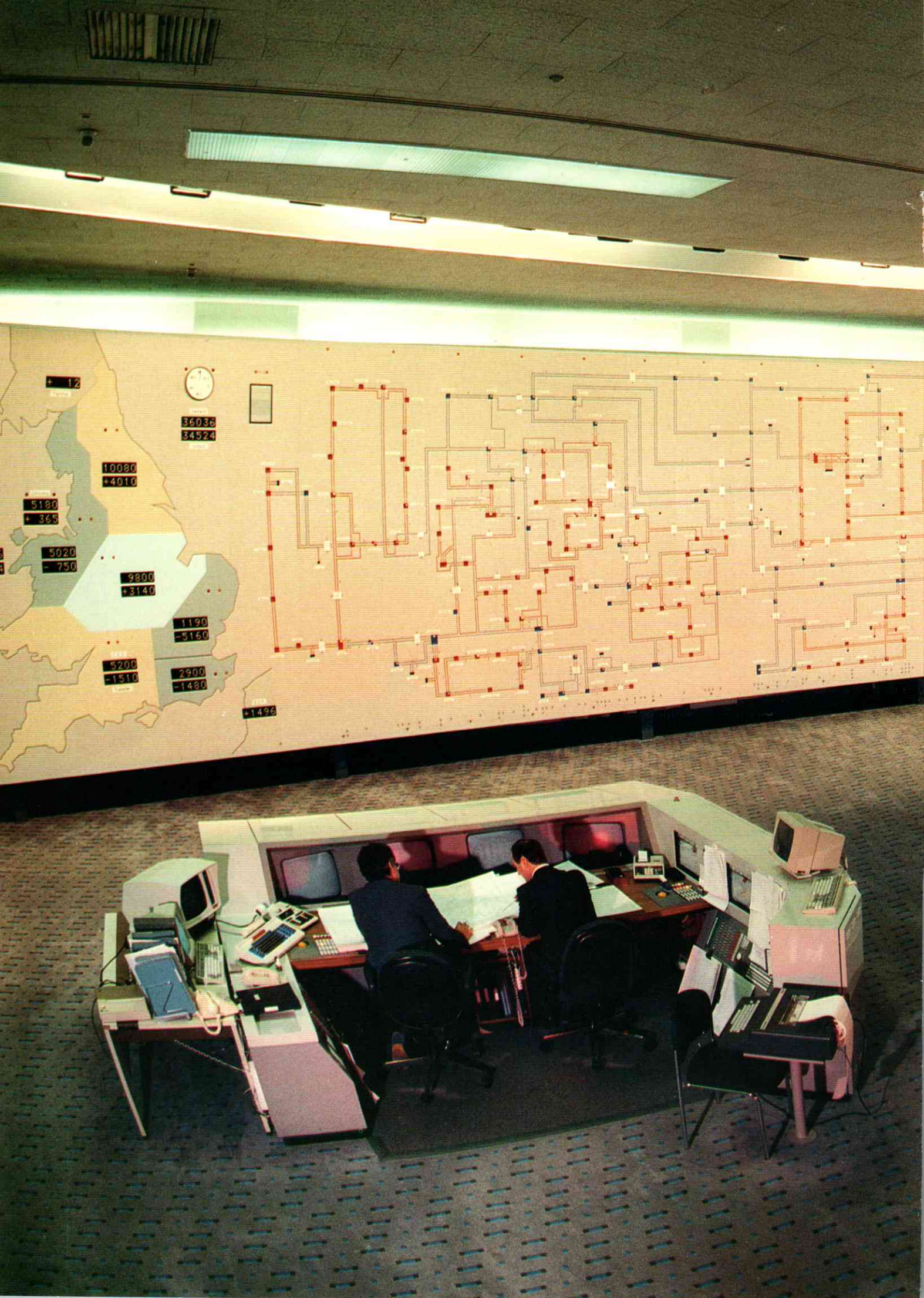
National Control determines the most economic way of supplying the customer demand and issues to each Area Control Centre an operating programme. This programme varies throughout the day, in order to achieve maximum economy from the changing pattern of customer demand and the price of available generation.

To satisfy the customer demand for electricity economically, all generators are ranked according to price, this ranking is known as the merit order. The merit order is used to ensure an economic ordering of generators throughout the day. Constant communication between National and Area Control Centres and power stations is a fundamental part of this process.

To achieve system security, it is necessary to operate some generators at higher outputs than strict adherence to the minimum price solution requires and, similarly, to operate some plant that would otherwise be shut down. In order to fully exploit the economic operation of the system, financial savings are balanced against the calculated risk of failing to meet the customer's demand in full. In this continuous process weather forecasts, provided by the Meteorological Office, are closely studied so that the effects of changing weather patterns can be taken into account in the balance of operating savings and risk. For example, there may be a sudden breakdown of a large generating unit, a thunderstorm creating a rapid rise in electricity demand, or the ending of a very popular TV programme resulting in people putting on lights and boiling electric kettles. The time of occurrence and/or magnitude of the demand increases are difficult to predict and are of a random nature. It would be uneconomic to keep conventional generating plant available to meet this risk. To cater for these unpredictable events, pumped storage generators at Dinorwig and Ffestiniog, which have the ability to respond quickly, are used. In addition, as final back-up, gas turbine generators with a fast start up capability can also be called upon.



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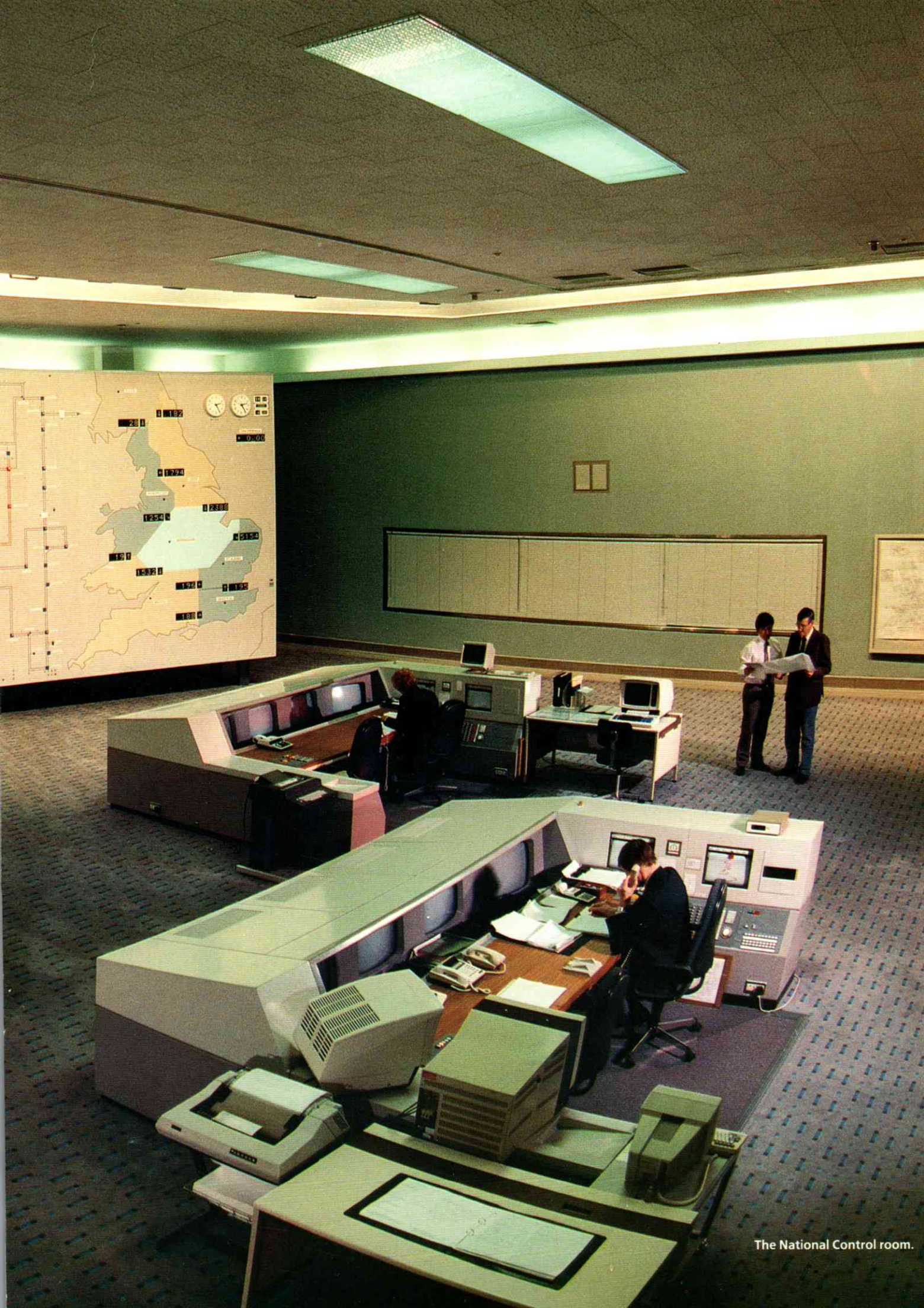


The National Control room.

National Control Centre

The Centre comprises the National Control room manned 24 hours a day, an apparatus room and office accommodation. In support of the Control Engineers are specialist groups planning the operation of the system for the next day and up to six weeks ahead and the Computer System Engineers who maintain and service the computers and associated equipment which provide the control room displays.

In the minute-to-minute operation of the power system continual surveillance is necessary of system configuration, real and reactive power flows and voltage levels, to ensure that the system will be reliable under all reasonable fault conditions. For National Control to operate effectively it is imperative that data concerning generating plant and system information are immediately available. Substantial amounts of data, termed on-line, including indications of switch positions and power system alarms, are transmitted several times a minute from power stations and grid substations to their controlling Area Control Centre and from there to National Control. This large amount of on-line information which describes actual operating conditions is marshalled and displayed with the assistance of on-line process control computers. These enable information to be stored and displayed selectively on visual display units (VDUs). Additionally, a wall display diagram is used to provide an overview of national minute-to-minute operating conditions.

The Control Engineers work at three specially designed control desks, each of which is provided with four 21-inch VDUs. Two of the desks are used respectively for system economics and system security, and the third is occupied by the National Control Engineer who exercises overall control room supervision.

There are duplicate keyboard controls on each of the three control desks for selecting the presentation of on-line grid system information on the VDUs. Each of the control keyboards comprises an alarm and interrogation panel, and a tracker ball for panning across pictures depicting loading conditions on the power system. The appearance is thus of a large map of the Grid which may be moved in any direction behind a fixed viewing aperture of a limited size. A "zoom" feature can magnify the part of the diagram under examination. Any one of the four VDUs per desk can be selected to bring up any computer display and thus each Control Engineer has four different displays directly available simultaneously. Twelve simultaneous displays are thus available in the National Control room as a whole.

Engineer instructing Dinorwig power station to commence generation.

Certain, more complex, sections of the power system associated with the main load centres require to be displayed separately and the Control Engineers are provided with facilities to call up a detailed representation of each of these sections. If an even closer examination is required, individual switching stations can be called up one by one to show circuit-breaker and operational disconnector positions and the power outputs of large generators. Graphical displays are used to show strategic power system parameters.

The visual alarms comprise six red indicator lamps, duplicated on each control desk, which flash when power system alarms are received. The alarms are annunciated and stored whenever system switches operate, lines become overloaded, or when system voltages or frequency exceed prescribed limits. Alarms are acknowledged by pressing the appropriate alarm button. Details of the cause of the alarm are displayed on demand.

All on-line power flows, both real and reactive, switch positions, system configuration and alarm data are updated approximately every 15 seconds and stored on disc. This provides a facility for on-line retrieval of operational data retrospectively at the control desk by simple enquiry. Samples of this data are automatically logged every minute from disc store to magnetic tape for subsequent system performance analysis.

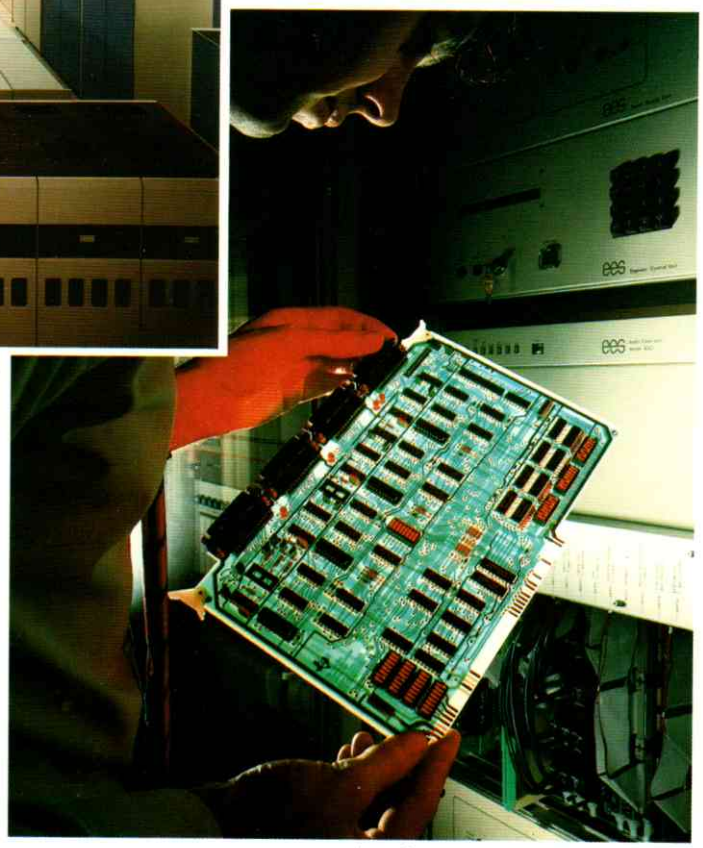
Computer terminals are located in the control room to provide Control Engineers with computer analysis facilities for system conditions. Two types of computational assistance are available and these may be classified as short-term predictive and immediate. In this context, short-term predictive computations are those covering the period from one to 24 hours ahead; immediate computations are those carried out in real time and concerned with minute-to-minute events as they occur on the power system.

To enable the system to be operated safely and economically, formal confirmation of detailed plans and system information is necessary, both for immediate implementation and for the longer term. The control room is furnished with a comprehensive communication system for receiving and transmitting information.

Administrative support desk

National Control computer equipment.

Main frame computer installation.

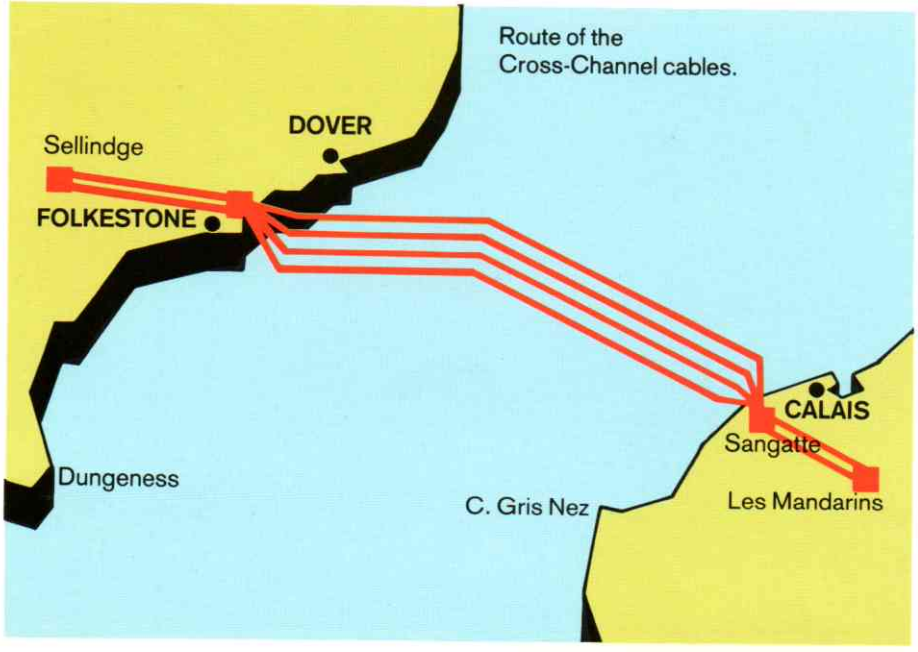


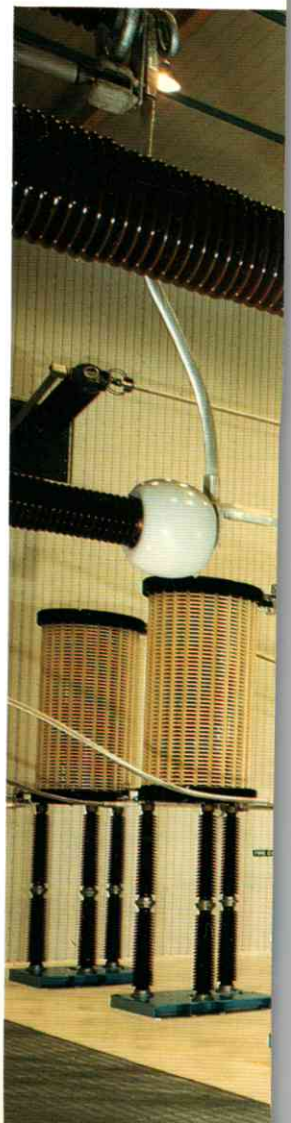
Inspection of computer printed circuit board.

The Electricité de France converter station at Les Mandarins near Calais.

Bilingual message system for cross-channel power flow instructions.

Sellindge converter station near Folkestone – the British end of the cross-channel link.

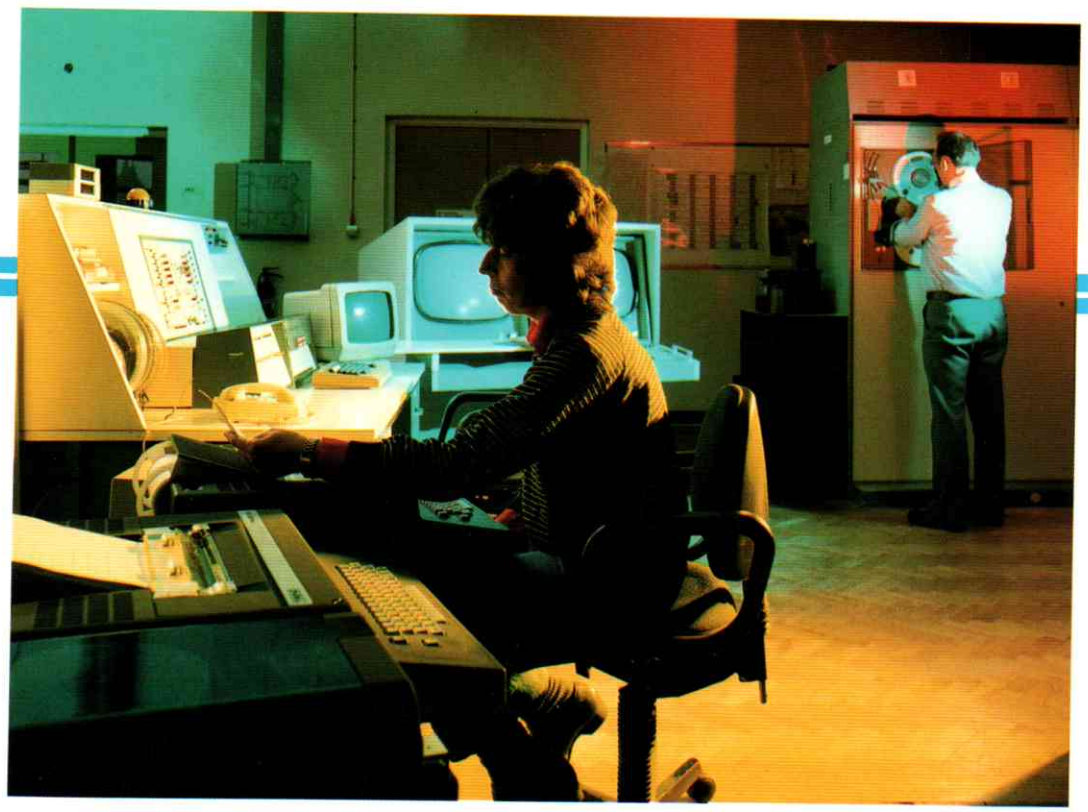




Computer Systems

The on-line information display facilities used in the National Control Room are provided by two Ferranti Argus 500 process control computer systems. These are connected in duplex configuration, one being the on-line master display computer and the other the standby computer – ready at all times to take over automatically the on-line display duties. However, with both on-line computer systems healthy, the standby computer is not idle but is used for the continuous on-line simulation of fault conditions to check power system security. The Argus 500 computer system is supplemented by a VAX 8700 computer system which provides additional and complementary displays for use throughout National Control. The on-line data required for the computers, telemetered flows, switch and overload indications etc are transmitted to National Control via the six Area Control Centres over private lines. A digital telemetry system, is used to transmit and decode the intelligence which is then fed into the Argus and VAX computers.

Short-term predictive computer studies include short-term demand forecasting, security assessment, system voltage control and reactive power investigations. These together with programs to store and analyse past system performance data for future reference, are carried out on the System Operation dedicated mainframe computer system. Access to the system, is provided by colour VDU terminals sited at strategic points within National Control. Output from computers studies can be examined on these VDUs or provided on one of the on site line printers.



National Control computer room.

Cross-Channel Link

There is a 2000MW capacity direct current (DC) link between England and France which is jointly operated with Electricité de France (EdF), and allows regular economic power transfers to take place between the two countries. Commercial trading is undertaken as part of the day to day operation of National Control.

The link itself, some 31 miles long, comprises eight cables laid in pairs in four trenches dug into the bed of the English Channel. These direct current cables are connected to the alternating current (AC) system by means of converter stations at Sellindge near Ashford in Kent and Les Mandarins near Calais.

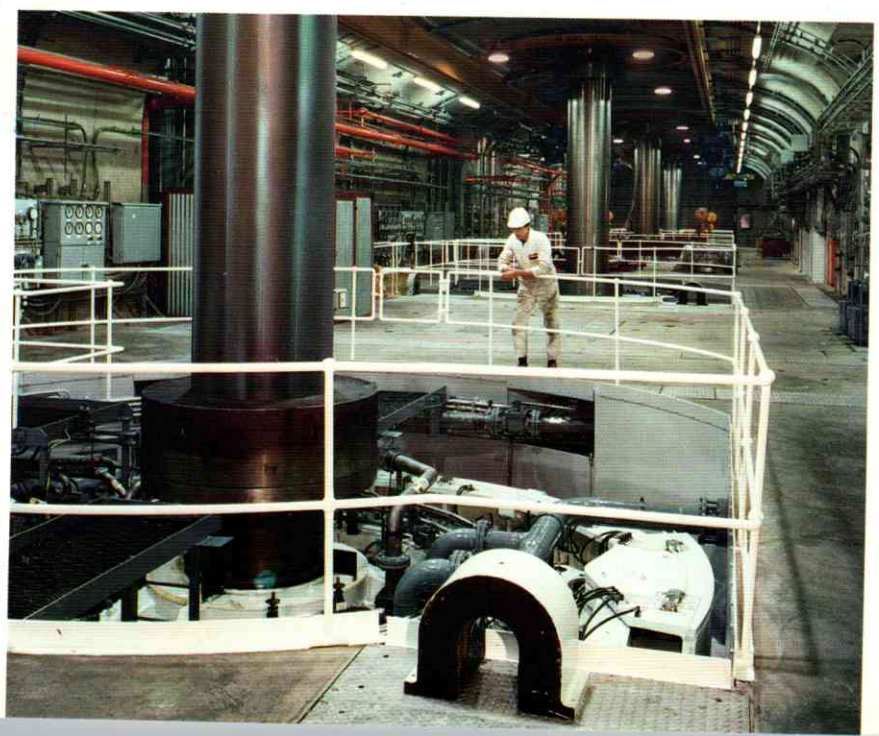
The economic incentive for interconnecting the power systems of England and France is the commercial opportunity for importing or exporting electrical energy. This is made more attractive by the one hour time-shift between the two countries and the differing pattern of the customer's demands.

Emergency system support is also immediately available to each country up to the maximum available capacity of the link provided that the system "under stress" is not at the same time importing at this maximum.

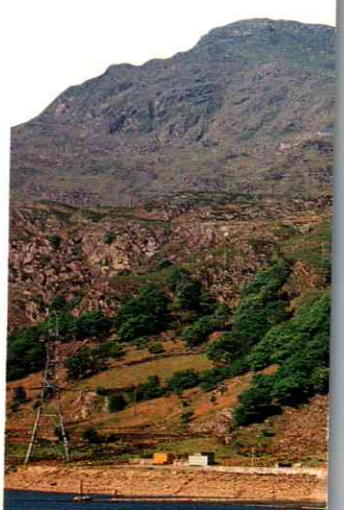
The environmental impact has been considerably reduced by the decision to build the converter station where the existing Dungeness – Canterbury overhead transmission line passes the site, thus obviating the need to construct additional lines. Great care has also been taken in the design of the converter station and its landscaping to minimise visual impact.

The valve hall at Sellindge converter station.

he lower reservoir of the Dinorwig pumped storage scheme.



The turbine hall ide a mountain orwig pumped storage power station, North Wales.

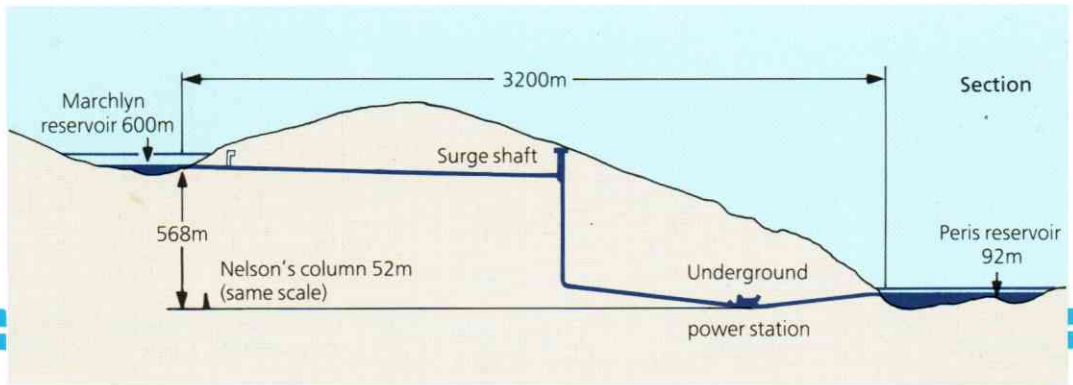


Pumped Storage Generation

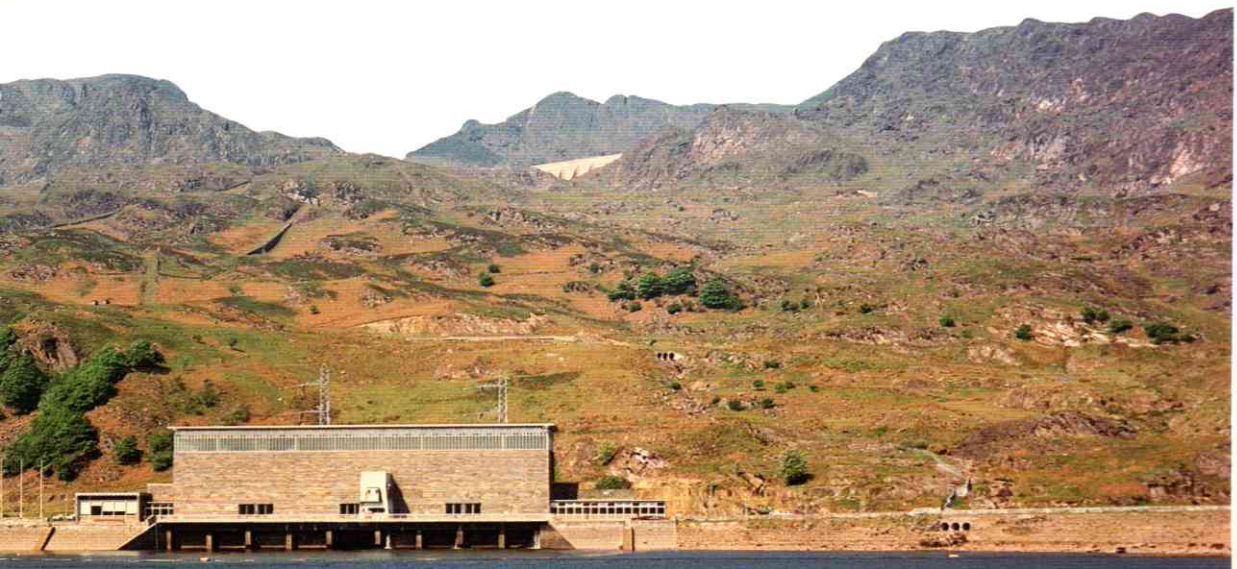
Pumped storage schemes have two water reservoirs, either natural or man-made, one of which is considerably higher than the other – thus mountainous or hilly terrain is a prime consideration in site selection. This type of scheme is of particular value when there are large variations in the daily demand profile as in England and Wales. Pumped storage plant has the ability to operate either as a generator when customer demand is high, thereby reducing the need to operate low merit, high priced generating plant, or as a pump when customer demand is low and there is a surplus of high merit, low priced, base load plant. Pumped storage plant can be used in the role of system reserve and National Control is responsible for determining and instructing the use of pumped storage plant for this reserve role and for in-merit operation.

There are two pumped storage power stations in England and Wales. Both of these stations, Dinorwig with an output capacity of 1800MW, and Ffestiniog with a capacity of 360MW, are sited in North Wales. Dinorwig is the largest scheme of this type in Europe and comprises six 300MW generators and associated equipment located deep inside the mountain underneath the old Dinorwig slate quarry. The two reservoirs, one some 1700 feet above the other, are connected by tunnels up to 31 feet in diameter through the turbines in the pumped storage station. When required to generate the energy released by the water travelling from the upper to the lower reservoir drives the turbines which in turn produce electricity. The water is then pumped back to the upper reservoir for future use, when customer demand and generating prices are low.

The plant is exceptionally flexible and can deliver full output in 11 seconds – from zero to full load. This rapid response enables the plant to assume the role of system reserve as mentioned above, and is very cost effective, because less economic steam plant which would otherwise carry out this function can be released and shut down.



Schematic diagram of the Dinorwig scheme.



Ffestiniog pumped storage power station.

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